

Knowledge Management at The MITRE Corporation

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Abstract

This chapter overviews the knowledge management (KM) history, strategy and practice at The MITRE Corporation. A non-profit organization working in the public interest in the domains of national security, aviation, and tax administration, MITRE has inculcated learning and knowledge sharing into its corporate culture. In particular, the chapter describes MITRE's KM roots, strategy, KM objectives, a chronology of KM practice, KM processes, KM repositories, communities of practice, expertise management, collaboration, return on investment, and KM benchmarks and measurement.

1. Background: The MITRE Corporation

The MITRE Corporation serves as an objective, non-profit corporation whose mission is to serve the public interest by creating solutions to pervasive, cross-organizational problems facing the federal government in civil aviation, tax administration, and national security. Its missions statement is: "As a public interest company, in partnership with the government, MITRE addresses issues of critical national importance, combining systems engineering and information technology to develop innovative, viable solutions that make a difference." Frequently this means enabling innovation, integration, and collaboration within and across public sector agencies, requiring efficient and effective knowledge management. The corporation's sponsors need help in being agile in response to world changes, ensuring they are interoperable with national and international partners, and countering the loss of government experts. MITRE has more than 4,000 employees distributed globally (principally throughout the US but extending to Europe and the Far East) and includes both technical and mission or operational experts. With sixty percent of the employees having more than twenty years of experience and about two thirds having advanced degrees, leveraging expertise is imperative. MITRE has extensive human assets who are in many circumstances placed in positions as trusted advisors to the government. Regular interaction among technical and domain experts distributed throughout headquarter and sponsor collocated units enables rapid and high quality creation of "solutions that make a difference"™.

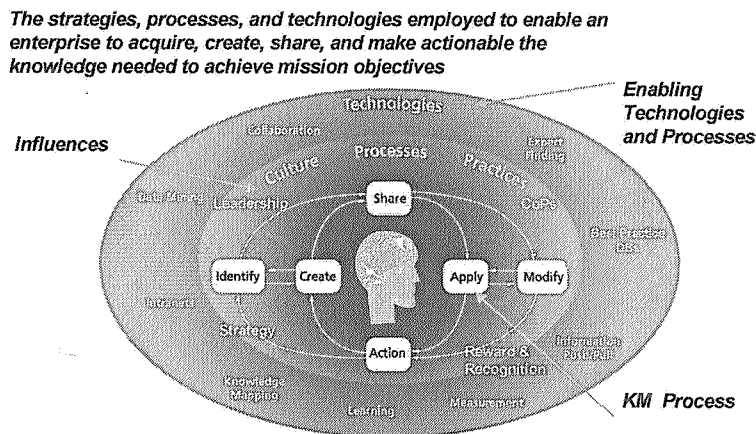


Figure 1: Knowledge Management Processes

Figure 1 illustrates MITRE's holistic approach to knowledge management, which we view as incorporating the strategies, processes, and technologies that enable our enterprise to acquire, create, share, and make actionable knowledge needed to achieve (corporate and sponsor) mission objectives. As Figure 1 illustrates, core knowledge management processes such as the creation, sharing and application of knowledge are performed within a context of the influence of corporate processes, practices and culture. They are further supported by a number of enabling technologies such as intranets, information push/pull, data mining, expert finding, expert practice databases, knowledge mapping, and so on.

This chapter first discusses MITRE's knowledge management strategy. Next we outline key events in MITRE's KM history. We then describe KM processes and technologies at MITRE. Finally, we outline our return on investment and benchmarking activities, concluding by indicating key lessons learned.

2. Knowledge Management Strategy

Figure 2 depicts MITRE's knowledge management strategy. The strategy aims to enhance mission outcomes by leveraging internal and external expertise and assets, supporting exchange of knowledge among individuals and groups (e.g., via technical exchange meetings), supporting knowledge reuse through capturing and sharing knowledge assets (e.g., lessons learned databases), and transferring knowledge captured explicitly in knowledge assets back to people (knowledge internalization). It also includes capture of knowledge from people to create tangible knowledge assets and internalization of knowledge within staff. MITRE's Director Knowledge Management serves as a corporate steward of the strategy, which is shared among the supporting and line organizations. This extends to business unit knowledge management champions, who help stimulate KM initiatives.

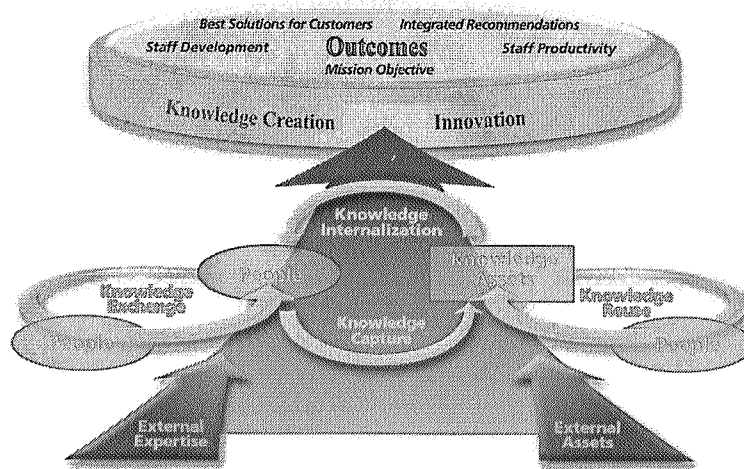


Figure 2: Knowledge Management Strategy

MITRE's knowledge management strategy targets outcomes including staff development and productivity, mission objectives, recommendations that involve the best knowledge integrated from across the company, and providing the best solutions for customers. As Figure 3 illustrates, MITRE recognizes a number of key enablers of knowledge management that are essential to its success. These include first an explicit articulation of knowledge management strategy, policies and processes that enable knowledge activities, planned measurement of success and failure, management of resultant content (intellectual products), technologies that facilitate knowledge management, and a culture that motivates it. This KM framework has been used for assessment at MITRE "to identify strengths and weaknesses (from an enterprise perspective) in our knowledge-leveraging capability, to benchmark the corporation against other KM leaders, and to recommend next steps" (Small and Tatalias 2001).

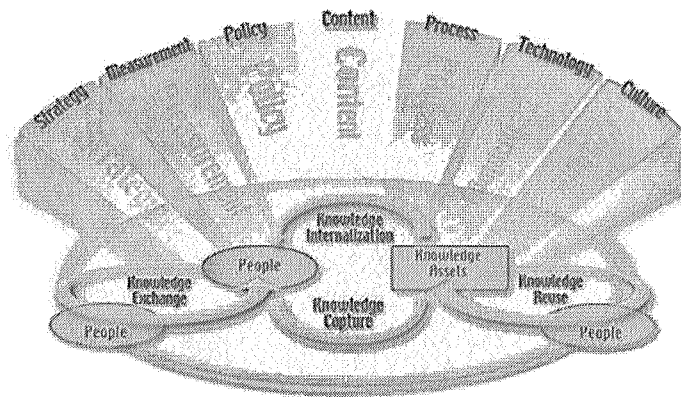


Figure 3: Knowledge Management Enablers

One of the mechanisms for establishing a culture of knowledge management includes high level executive commitment and motivating incentives to encourage KM behaviors. This commitment is implicit in MITRE's three corporate values: "people in partnership", "excellence that counts", and "outcomes in the public interest". These values are reflected in performance and development plans for each manager and employee. In addition, KM activity and behavior is incentivized through a formal and visible KM Awards Program, described below. Finally, an environment of innovation from the line organizations and collaboration with the infrastructure support organization ensures the best solutions get deployed corporately. We next described how this comprehensive KM strategy developed over time.

3. Knowledge Management History

Figure 4 illustrates an abbreviated history of knowledge management at MITRE. The top portion of the time line indicates key technical events, the bottom portion key organizational events (underlined), awards, and publications (*italicized*). As is evident in key organizational events on the lower half of the time line, knowledge management played a key role from the very start of MITRE. The MITRE Corporation was founded in 1958 to address the government's need to create the Semi-Automated Ground Environment (SAGE), an integrated system to defend the US against the threat of Soviet air attacks. Creating such an unprecedented system required a unique combination of military, operational, and technical knowledge and experience from government, industry and academia. This need for integrated knowledge steadily increased as the corporation grew in scope, size and geographic extent, including the formation of three federally funded research and development centers for defense, air traffic control and tax administration. Over the years, the corporation embraced collaboration as a key to knowledge sharing and dissemination (see collaboration.mitre.org). Initially, informal "cluster" or "specialty" groups emerged to enable communities of experts to collaborate. In the mid 1980s, technical centers of excellence were established in areas such as software, networking, artificial intelligence, and economics to enable effective allocation of scarce expertise, efficient knowledge sharing, and peer review for quality assurance. We further describe these and other communities of interest in Section 6 below.

A number of early technical achievements in KM are equally notable. In the late 1980s the corporation began to invest in videoteleconferencing systems to enable managers to overcome geographic separation. A so called Tier I VTC between Bedford, MA and Washington D.C. supporting about 10 people on each end went operational in 1988. VTCs soon grew to a ubiquitous corporate wide service of a common concern, evolving into modern "Team rooms" with shared VTC, individual networking, and collaboration tools. By 2002, MITRE corporate supported 34 VTC facilities in Bedford, 29 in Washington, and 35 at sites worldwide enabling approximately 20,000 VTC meetings per year. There also was experimentation with physical collaborative space design, including an open floor for the Economic and Decision Analysis Center (EDAC) in Washington D.C, shared laboratory and pantry spaces in new or renovated MITRE Washington buildings, hotelling spaces for temporary staff visits, and shared spaces (e.g., coffee or discussion areas) in various facilities.

KM Technical Events

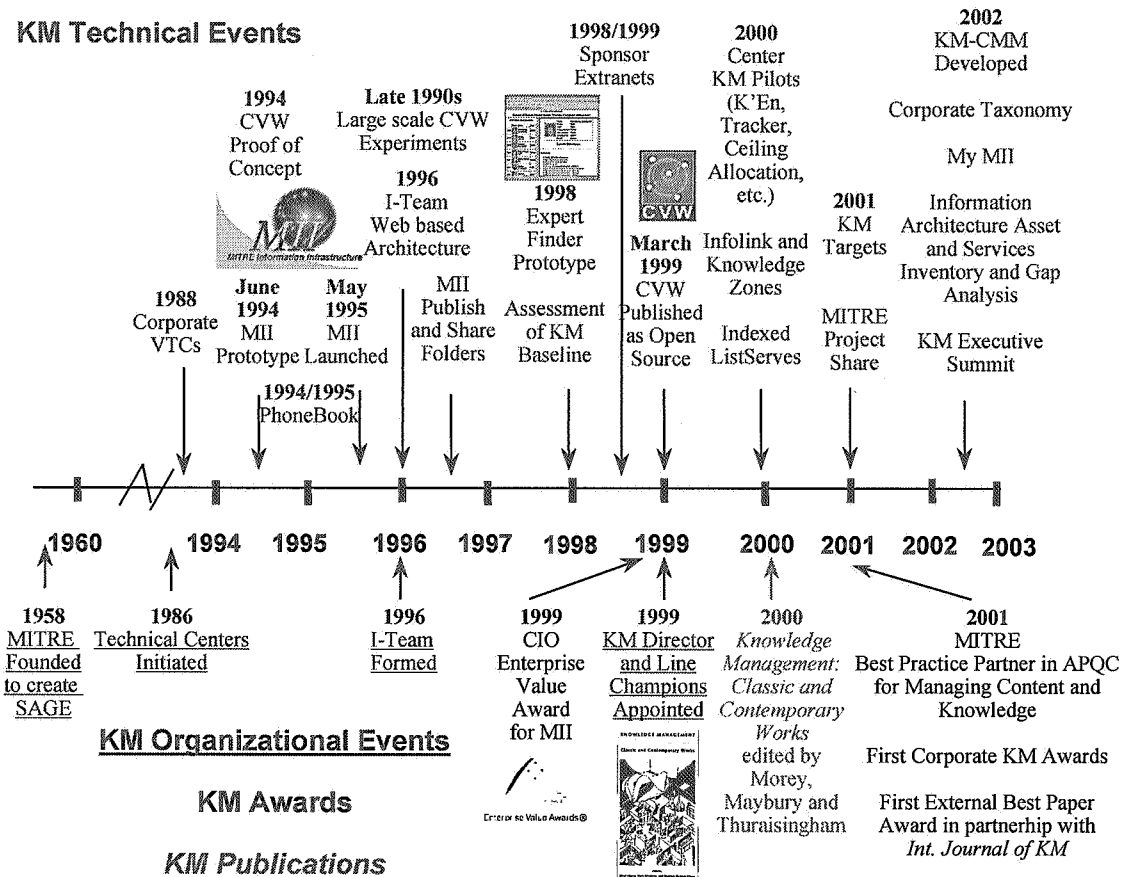


Figure 4: Knowledge Management History

With the ushering in of the digital age, MITRE found a need to dramatically increase the ability to leverage and share knowledge corporate wide. Accordingly, in June 1994, the corporation initiated work on a corporate intranet for integrated administrative and technical information and services that would establish a corporate knowledge base and further accelerate collaboration across organizational and geographic boundaries. This arose from innovations in various parts of the company, including work on information discovery and retrieval in systems such as the Center for Advanced Aviation Systems Development (CAASD) Resource Discovery System (CARDS) (Wherry, Krause, and Sciambi 1994). Corporate leaders believed this was essential to bring the corporation to bear on complex, pervasive problems faced by various government agencies. In May 1995, the MITRE Information Infrastructure (MII) was released to the corporation, a central element of it being the “phonebook” which pulled together all information about an individual (administrative, financial, technical) into a single web page. In 1999 MITRE was awarded the CIO Magazine Enterprise Value Award for the \$7.2 million investment in the MII which netted an ROI of \$62.1 million in reduced operating costs and improved productivity (Young 2000). More important than cost savings was the indirect impact such a system had on MITRE sponsors. For example, this included a culture of collaboration enabled by the use of the MII articulated an internal mantra that MITRE “collaborates internally in order to integrate externally.”

In 1996, MITRE’s CEO chartered the Innovation Team (I-Team), a corporate group of senior information technology officers and directors charged with governing our information technology resources and investments, including those in knowledge management. Soon thereafter the I-Team recommended a web-based architecture. A Knowledge Management subteam was established and in 1998 a corporate baseline of knowledge management was performed. A Director of Knowledge Management was appointed in 1999, together with KM champions within each of primary

line organizations. Infrastructure continued to evolve, including a unified messaging (i.e., electronic mail) architecture, click and drag publishing services, and shared electronic spaces for informal information exchange among staff (called “transfer folders”). By 2002, a quarter of a million documents were published in project folders and over one million documents and presentations were shared in staff personal transfer folders, a predominant means of information knowledge sharing. In addition, MITRE established external open and shared repositories (now 22), such as collabortion.mitre.org, which shares unclassified information on collaboration tools, methods and lessons learned among government, industry and academic experts. Analogously, cve.mitre.org provides a common vulnerabilities enumeration for the broad information assurance community. In contrast, extranets and portals were initiated in 1998 to provide shared, secure digital space for private internal/external communities. By 2002 extranets were set up for 39 communities containing a total of 35,000 documents, and portals are provided for 12 communities hosting a total of 23,000 documents. In 2001, MITRE was recognized by the American Productivity and Quality Council (APQC) in the category of Managing Content and Knowledge.

Innovation to support knowledge management and collaboration has been continuous, including the creation, experimentation, and open sourcing of the Collaborative Virtual Workspace (cvw.sourceforge.net), described in a subsequent section. Also, the Expert Finder prototype for finding experts helped launch MITRE into the area of expertise management. A MITRE media center allows for live broadcast of technical events (e.g., keynote speakers), the library of which contains 600 archived requests. Typically 100 individuals across the corporate live view these events.

MITRE benchmarked various KM strategies, processes and measurement activities and captured and shared our learnings in the collection, *KM: Classic and Contemporary Works* (Morey, Maybury, and Thuraisingham 2000). In collaboration with the *International Journal of Knowledge Management*, royalties from this book are contributed annually to a best paper award that recognizes the most significant external contribution to KM theory/practice. Related, we have developed a KM Capability Maturity Model, described in the benchmarking section. A KM Summit in November 2002 for our high ranking government sponsors shared valuable lessons learned across government agencies and senior leaders of KM initiatives.

Finally, recognizing the importance of incentivizing knowledge sharing behaviors, the corporation created two annual awards. This includes a \$5000 President’s Knowledge Management Achievement, presented by MITRE’s CEO, and ten \$1,000 Corporate Knowledge Management Recognition Awards, presented by MITRE’s CIO. Corporate KM Awards aim both to recognize individual and group efforts that demonstrate the knowledge-sharing behaviors critical to our success and also to further encourage knowledge management contributors across the organization. A committee reviews nominations and considers recognition of the following classes of knowledge management behavior:

- 1) The nominee creates or applies KM techniques to broaden and strengthen corporate expertise or learning communities; creates new knowledge; captures, shares, discovers, and reuses knowledge
- 2) The nominee enables others (including customers and employees) to apply KM techniques and achieve knowledge sharing by providing the environment and tools for creating, capturing, discovering, sharing, and applying corporate knowledge; acting as a knowledge-sharing advocate and catalyst for change; creating or leading new KM techniques and processes that are employed by others.

The internal KM awards were created to encourage MITRE employees to make practicing KM principles a regular, and important, part of their work. The awards recognize individuals and groups who demonstrated extra initiative and follow-up in making information available and accessible to everyone. One recipient, Alan Piszcz, a chief engineer for the Applied Information Technology Center in Reston, Virginia, created a web site directed for his peers. Created mostly on his own time, his site contains a wide range of information on projects, expert colleagues and sponsors, and past and future technical exchange meetings organized by technical and defense-related topics.

4. Knowledge Management Processes

Managing and enabling MITRE's distributed intellectual resources is a daunting challenge. Figure 5 illustrates an abstract view of MITRE's KM processes. Our perspective is that processes must provide full knowledge life-cycle management, to include Web-based expert finding services, capture/reuse of knowledge and lessons learned, project and partnership creation (leader identification, team formulation, team facilitation/collaboration), and knowledge delivery. As is indicated in the figure, a knowledge infrastructure providing access to information, tools, and people is a central element to our process.

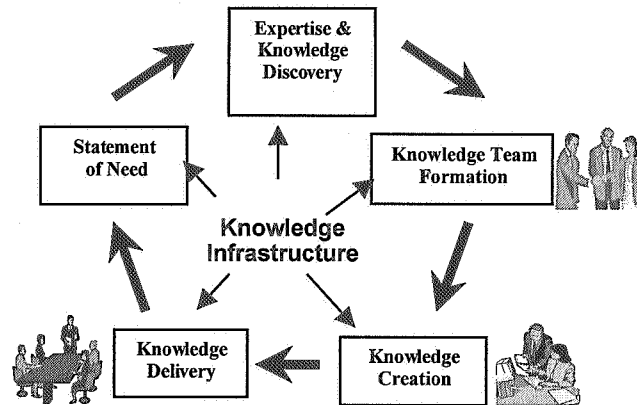


Figure 5: Knowledge Management Processes

To enable effective distributed knowledge management, MITRE employs global video teleconferencing, an innovative MITRE Information Infrastructure (MII) intranet, as well as public key infrastructure (PKI) enabled extranet services. Knowledge resources such as "ask the expert," on-line knowledge repositories of risk management experience (RAMP), and system engineering lessons learned (Systems Engineering Program Office (SEPO)) are also available. Tools for staff and project discovery, information sharing (e.g., transfer folders) and virtual place-based collaboration (e.g., VTC, instant messaging, MITRE's CVW (cvw.mitre.org)) are used to enable agile team formation and support. Finally, a collaborative culture, organizational structures (e.g., technical councils, technical centers of excellence), special roles (e.g., sponsor focal points, strategic outcome leaders), as well as regular knowledge exchange meetings (called Technical Exchange Meetings or TEMs) support the process shown in Figure 5.

Part of MITRE's business model also entails the identification and employment of expert teams from outside the corporation. An illustration of effective knowledge management techniques used by the government is the Science and Technology Expert Partnership (STEP) program (www.house.gov/international_relations/full/oversight/maybury.htm), managed by the Scientific and Technical Intelligence Committee (STIC). The mission of STEP is to "ensure that scientific and technical analysis for the intelligence community represents considered judgement by the highest caliber experts in the United States." STEP maintains a network of nationally recognized experts from a broad range of scientific and technical areas. STEP facilitates collaboration between experts and intelligence community analysts to create classified and unclassified studies that address important national concerns. This agile form of virtual organization on demand has produced a variety of cost effective results on a number of scientific and technical topics.

The need to leverage knowledge across individuals and organizations, in part, motivated the creation and mapping of knowledge repositories and support for communities of interest. We describe these in the next two sections.

5. Knowledge Repositories and Knowledge Mapping

Repositories of knowledge include humans and technical collections. As shown in Figure 6, the MII includes current

events (including technical exchanges), administrative, and technical information in columns one, two, and three, respectively. Below this the user can find information on “how to” do various knowledge management activities such as publishing or sharing information, finding resources, or adding knowledge sharing mechanisms. As indicated above, MITRE’s primary knowledge repositories are project folders (a quarter of a million documents), staff personal transfer folders (over one million documents and presentations), external repositories (22) such as collaboration.mitre.org or cve.mitre.org, and secure extranets (35,000 documents for 39 communities) and portals (23,000 documents for 12 communities). These electronic repositories represent a dramatic shift from traditional hard copy technical reports which have diminished significantly.

Figure 6: MITRE Information Infrastructure



Under the administrative column the user can find corporate information and services, personal desktop computing information, and financial information. Under the technical column, under the “MITRE Expertise” subheading, the MII facilitates access to human experts by explicitly identifying MITRE expertise such as chief engineers, the Systems Engineering Process Office, Technical Area Teams, and so on. Corporate technology program results and “Research Resources” such as information repositories, digital libraries, lessons learned databases (e.g., in COTS, systems engineering, risk analysis), and so on are also directly available. Finally, major technology or organizational magazines are also available electronically via the MII such as MITRE Matters, and in some cases directly externally. The Edge (www.mitre.org/edge), research news, knowledge @ MITRE, mITre advisor, SEPO notes, and project/technology showcase.

In order to facilitate navigation of this knowledge, MITRE provides various manually designed “views” into the information space oriented around events and repositories related to requirements for

employees playing specific roles such as new employee, manager, or secretary (notice the “Views” section under the Administrative column in Figure 6.). Also, the MII provides manual knowledge mapping (e.g., knowledge zones) of technical repositories, and we are experimenting with semi-automated mapping to create comprehensive and intuitive views to ease knowledge exploitation of both formal and informal repositories.

The MII also contains strategic knowledge collections worthy of note. For example, MITRE's Risk Assessment and Management Program (RAMP) provides an intranet repository of project risks, risk mitigation strategies, and lessons learned. RAMP contains more than 400 project-specific risks from over 180 projects in both defense and aviation. Risk experiences from dozens of ongoing projects are added each year. “The objective of RAMP is to offer project managers a knowledge management tool to help identify and quantify specific areas of risk on analogous projects, review risk mitigation options and actions, and assess how effective such actions might be at reducing cost, schedule, and performance risks on their projects” (Taub 2000). For example, a staff working on a project that involves integrating commercial off-the-shelf (COTS) software can consult RAMP to learn about risks that have been encountered in similar projects or to find out how to assess possible risks before software system acquisition planning. In addition to RAMP, MITRE's Systems Engineering Process Office (SEPO) manages knowledge resources on systems engineering and acquisition reform. Whereas RAMP is a knowledge repository, SEPO provides expert systems engineers who work in the field on projects where they gain new and apply existing knowledge. Their knowledge is systematically captured and shared out to MITRE staff.

One of the most prominent COIs is the Innovation Team (commonly called the I-team). Chartered by the President and Chief Executive Officer to ensure that MITRE achieved and promoted innovation across the company, a team of information technology leaders (the Innovation or I-Team) was founded with three major responsibilities:

- Be accountable for MITRE's information technology related resources, systems, processes, and activities
- Set MITRE's direction for implementing state-of-the-art information technologies
- Establish MITRE's reputation in the information technology community.

Since its creation, the I-team has provided key strategic direction and focus leading to many important IT advancements for MITRE, including the following:

- Chartering and use of collaborative, expert subteams to recommend policy or technology directions to the group
- Adoption of a web-based information architecture that is independent of vendor or implementation that specifies standards such as IMAP/POP for messaging, LDAP for directories, X.509 for certificates. This was the foundation of MITRE's award-winning MII.
- Establishment of a corporate "team room" paradigm, providing for integrated network and video teleconferencing (VTC) capabilities (moving into broad use in MITRE's new facilities). Also the use of shared applications collaboration software (e.g., Microsoft Netmeeting) and instant messaging (AOL IM) during meetings but with social protocols (e.g., don't read email during presentations/discussions, only used IM for functions related to business of meetings such as tasking a subteam or obtaining required technical or budget information).
- Adoption of innovative "model office" space use concepts for MITRE's new campus facilities and numerous site locations
- Evolution of corporate shared vision and interoperability for laboratories, significantly increasing collaboration among researchers and achieving greater utilization of MITRE's research computing infrastructure
- Evolution toward computer-telephony integration and convergence of corporate voice and data infrastructures
- Transformation of the corporation's processes and information infrastructure from traditional business practices to an e-business paradigm.
- The launching of *The Edge*, MITRE's corporate Information Technology Newsletter, and *The Edge Perspectives*, MITRE's issues paper to which is intended to capture MITRE's collective wisdom on critical technology issues. Each *Perspectives* issue defines strategic topic, outlines key issues, and articulates MITRE's recommended practice within various sponsor or acquisition environments. The Edge also aims to have shared guest editorships, especially across operating center and/or geographic boundaries to foster collaboration through the process of shared editorship/stewardship of each special issue.

Finally, several years ago MITRE launched Knowledge Partners (Maybury 2000a) to help MITRE tap the vast reservoir of knowledge embodied in its retirees through Reserves at the Ready, a pilot project designed to offer highly qualified, MITRE retirees opportunities to support short-term work program requirements. When becoming a member of the reserves, MITRE retirees become Part Time on Call employees with their resumes available via the MII. Project leaders can call upon them to perform project work that draws upon their typically extensive experience base or to mentor new or recently promoted staff. Upon completion of assignments, reserves update their online resume to include current experience.

In addition to cross corporate teams, MITRE actively engages with and/or facilitates the creation of communities

of interest for our sponsors. We described the STEP program above. Related, in 2002 MITRE was asked by the Advanced Research and Development Activity in Information Technology (ARDA) to establish the Northeast Regional Research Center (NRRC) for the intelligence community. The NRRC rapidly forms industry/academia/government teams to collaboratively work in extended (two month) workshops to create revolutionary advances on complex intelligence research and development challenges such as in advanced question answering or content extraction from video. Knowledge exchange among government and experts from industry and academia in the Northeast region is facilitated by digital archives (nrcc.mitre.org), team rooms, and a series of focused, eight week workshops to actively solve IC problems.

As suggested above, MITRE provides a range of infrastructure and process mechanisms to enable expert communities of practice, just few of which include:

- Shared user distribution lists that allow self-enrollment to form email groups
- MITRE news groups, which facilitate threaded discussion
- TEx, where TEMS are announced and listed on the MII - arranged by experts, focused on learning/sharing
- MII lists for cluster groups and specialty groups
- Extranets to enable secure information sharing with our sponsors
- Ubiquitous VTCs and digitally enabled team rooms to enable cross site collaboration

Finally, in addition to the 25 annual TEMs, an annual corporate technology symposium, occurring both in Bedford and Washington, enables staff, management, and sponsors alike to share and discuss recent innovations.

7. Expertise Management

Recognizing early on the essential nature of experts in knowledge management, MITRE created and piloted tools to address fundamental aspects of expertise management including the identification of experts, the classification/characterization of experts, their validation, and support for expertise collaboration. Distribution of staff, decreasing project size, and cost/time pressure create a need to leverage enterprise expertise by quickly discovering who knows what and forming expert teams. Those in need typically have little or no means of finding experts other than by recommendation. As indicated in the previous section, these include manually created and maintained repositories of experts (the “MITRE Expertise” subheading under the technical column in Figure 6). MITRE has also innovated in the automated discovery of individual experts and expert communities of practice, two areas we next describe.

7.1 MITRE's MII Expert Finder

Unfortunately, busy experts do not have time to maintain adequate descriptions of their continuously changing specialized skills. Past experience with “skills” databases at MITRE indicates that they are difficult to maintain and quickly outdated, especially considering an industry-wide average employee attrition rate of greater than 10% in high-tech fields.

MITRE's MII Expert Finder (Mattox, Smith, and Seligman 1998) fills this gap by mining information and activities on the MII related to experts and providing this in an intuitive fashion to end users. Figure 7 illustrates the system in action. In this example, a user is trying to find human computer interaction experts in the corporation. When the user searches using the term “human computer interaction,” the system ranks employees by the number of mentions of a term or phrase and its statistical association with the employee name either in corporate communications (e.g., newsletters) or based on what they have published in their resume or document folder (a shared, indexed information space). Integrated with MITRE's corporate employee database, employees are ranked by frequency of mentions,

pointing to sources in which they appear.

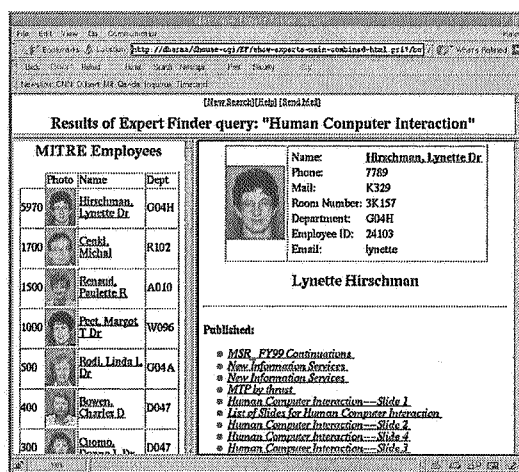


Figure 7: MII Expert Finder “Human Computer Interaction” Example

The MII Expert Finder exploits the MII, and thus avoids maintaining information internally. By doing so, Expert Finder operates in real-time, using the most recent information available to locate experts. The MII contains many different sources of information that can be used to locate relevant expertise. Staff members can easily and quickly publish documents in individual staff “document” folders on the MII. These include technical papers, presentations, resumes, and home pages. Also, information is published about MITRE employees in project descriptions, announcements, and internal and external newsletters. At MITRE, a common text search engine indexes all of these documents.

The original goal of Expert Finder was to place a user within one phone call of an expert. However, in the majority of the cases tested, reasonable candidates for the title “expert” are listed as the top three or four candidates, where the likelihood of randomly selecting a correct expert is the total number of experts divided by 4,500 total staff, often significantly less than a one percent chance of getting any right. In an evaluation we contrasted the performance of ten technical human resource managers, professionals at finding experts, with the MII Expert Finder for the task of identifying the top five corporate experts in specialty areas including data mining, chemicals, HCI, network security and collaboration. Measuring *precision*, the degree to which a staff member found by the MII Expert Finder is considered expert by humans, and *recall*, the degree to which a priori human-designated experts are found by the MII Expert Finder, the systems performed on average about 40% precision and 30% recall (Maybury, D’Amore, House 2000, 2001). This was more than adequate to get a staff to an expert within one phone call.

7.2 MII XpertNet

Just as individual expertise management is important, so too is discovery of teams of experts. A key organizational component of MITRE’s knowledge management strategy, corporate Technology Centers conduct applied research in a number of technology areas related to the sponsor's mission. As such they often partner directly with project departments, forming teams with diverse but complementary skills and problem knowledge. Organizationally, staff working related technologies and problems could be modeled as social networks that form the basis for abstracting expertise. Mapping expertise facilitates collaboration and provides a basis for directing strategic investments and optimizing resource allocation. XpertNet is designed to extract expertise networks and integrate them into the overall expertise management system. XpertNet works without user queries to identify expertise areas; a distinction between it and other expertise locator tools

XpertNet uses statistical clustering techniques and social network analysis to automatically infer networks of people having related skills and interests. Networks are extracted from various work contexts or activities such as projects,

publications, and technical exchanges. Clusters are mapped to an expertise area description, a membership list consisting of MITRE technical staff and their degree of membership, and a list of content items on which the cluster is based. Information from published documents, public share folders, project information, and other sources are used to assess level of expertise. Higher levels of expertise are associated with factors such as document authorship, explicit reference or citation, network centrality, personal Web pages, and project membership. Lower expertise levels reflect fewer expertise indicators and possibly counter-indications such as being a member of the administrative staff. Currently, XpertNet incorporates domain independent models of expertise; domain-specific expertise models are expected in niche technology areas (e.g., Perl programming).

XpertNet has been directed at specific MII workspaces. Generally, items are simply selected from each workspace; however, large workspaces containing thousands of items are sampled to reduce processing costs. For example MITRE Public Share Folders consist of a wide range of documents provided in a user-controlled directory for sharing with interested MITRE staff. Share folders often contain hundreds of items or more, are quite diverse and may contain items that are fairly recent or several years old. Given the wide disparity in folder characteristics, a sampling frame ensures that a representative number of items are extracted for each user, that topics are adequately covered, and that the sample reflects recent work. In effect, the sampling scheme provides a statistically sound basis for working with a subset of a potentially large population of work artifacts. A signature is generated for each object sampled. Each signature contains person identifiers (e.g., employee ID, phone number, position level), workspace descriptor (e.g., Technical Exchange Meeting, Research Project, and Public Share Folder), and expertise indicators (e.g., descriptive phrases) extracted from activities or stored content.

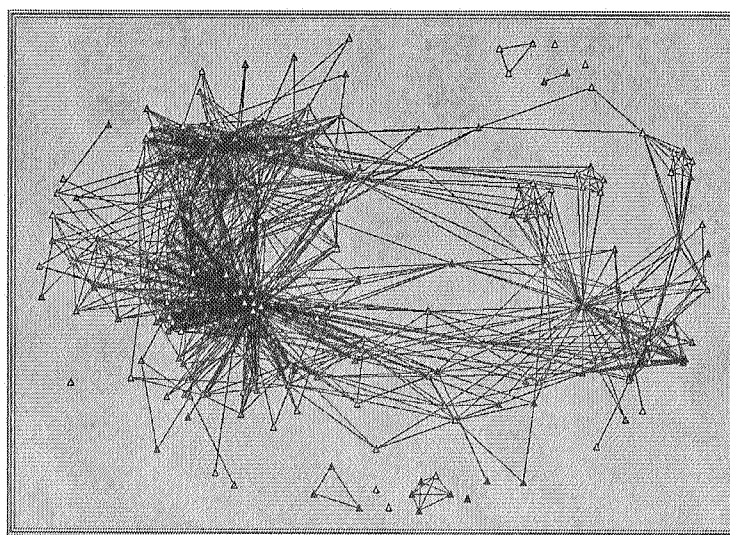


Figure 8: Social Net Analysis: Arcs based on co-work. Note isolates and structural holes

An example of an expertise network, with members identities masked out, is provided in Figure 8. In this "map," nodes (triangles) represent people within the organization, the color of each node relates to the particular organizational entity (division, department, etc.) of each network member, and links between nodes indicate significant shared project participation and/or overlap in published content. Thickness of the links can be varied to corresponds to the strength of the association between these entities. From this network we can identify (component or isolated) subnetworks, orphan nodes, nodes that serve as bridges between networks. This "knowledge network" can be a more accurate, dynamic view of organizational knowledge sharing as opposed to static organization charts.

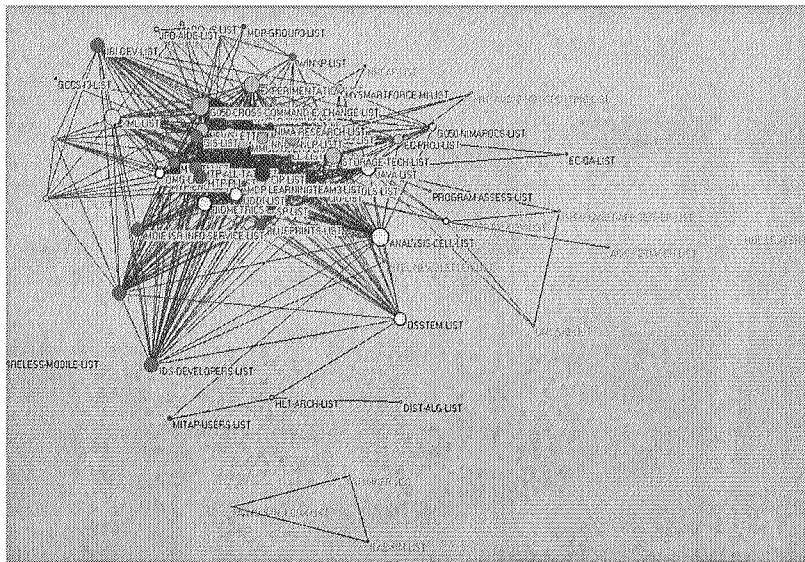


Figure 9: Dynamic Community Tracking: Shared Users on Listserves

A similar analysis can be performed by looking at indicators such as shared membership and/or share content in mailing lists to discover relationships among various communities of interest. For example, Figure 9 illustrates relationships among MII mail lists (representing communities of interest) where nodes are lists (e.g., BIOMETRICS, ANALYSIS-CELL, or MITAP-USER), and arcs are overlap in membership or content.

XpertNet was evaluated at MITRE's Information Technology Center. Initially, expertise networks, generated from user surveys, were compared to automatically generated expertise networks. The survey was administered to roughly 10% of the Center's technical staff. Each survey respondent nominated MITRE staff that had expertise in the specified technology area. Respondents nominated those they worked with as well as other known corporate experts, typically outside their home organization. Initial results yielded four core expertise areas: Collaboration, Knowledge Management, Advanced Instructional Training, and Language Processing. These areas match up fairly well with 4 separate departments within the Center; however, many of the identified experts come from other organizations outside the Center.

Standard precision and recall measures, traditionally used in information retrieval experiments, were used to assess the overlap between the manual and automatically generated networks. The surveys did not provide a ranking of experts, so precision at a particular cutoff was defined as the percentage of manually identified experts who were in the automatically generated list. Similarly, recall at a specified cutoff is the percentage of automatically ranked members who were in the total manually generated expert list. As shown in the combined table/graph in Figure 8, approximately 70% of the top ten automatically identified experts were in the manually identified list. Precision dropped about 10% when computed over the top 20. Recall, at the top 10 cutoff, was also fairly high, but this is partly a function of the relatively small number of experts identified by humans. Looking at the top 30, approximately 75% of the experts were identified automatically with approximately 50% accuracy.

8. Place-based Virtual Teams

Key to enabling collaboration is providing the ability for distributed teams to work together independent of time and location. MITRE has provided leadership in the creation and application of place-based collaboration environments, notably the Collaborative Virtual Workspace (CVW) (Spellman et al. 1997). CVW and its commercial successors are based on a "virtual building" metaphor where teams can communicate, collaborate, and share information, regardless of their geographic location. CVW enables virtual co-location through persistent virtual rooms, each incorporating people, information, and tools appropriate to a task, operation, or service. As illustrated in Figure 10, the upper left-hand side of the CVW Client Interface displays text chat, users in the current room, and shared data.

The virtual building floor plan shown in the middle upper portion of Figure 10 gives the users a sense of where they are in virtual space.

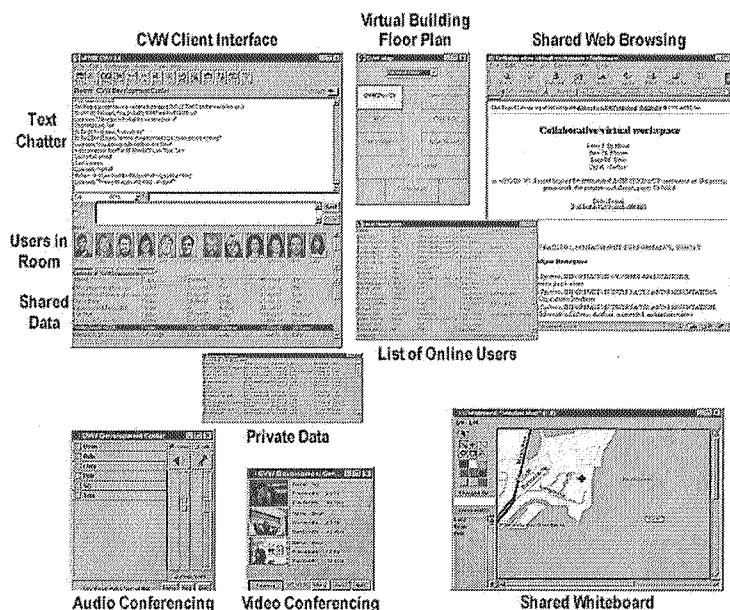


Figure 10: CVW

Users have navigational facilities, such as the ability to browse rooms and floors just as one could do in a physical building. In each interaction device such as chat, whiteboard, and audio/video conferencing, active participants are displayed and individual contributions are visibly attributed to individuals. For example, in the audio conferencing tool displayed in the lower left-hand portion of Figure 10, the current speakers in the teleconference are listed in the left-hand side of the display. As each user speaks, their name is highlighted.

Similarly, in the shared whiteboard displayed in the lower right hand side of Figure 10, the active users in the whiteboard conference are listed in the left hand side of the display just below the color palette. As users perform white board actions, their identities are signified in the cursor via an abbreviation and their persistent annotations are attributed with their identity. This allows users who join in subsequently in the session to have awareness of the source of annotations to the whiteboard.

Placed based collaboration environments have enabled real-time, virtual knowledge sharing for both air operations and intelligence analysis (Maybury, D'Amore and House 2001). Documented benefits have included, as much as 30% reductions in task time, 50% increase in awareness, and as much as 10 fold reduction in required staff for similar tasks, including reductions of on site "forward based" personnel. By providing global access and by transformation of serial processes into parallel one, place-based collaboration environments have enabled government organizations to realize visionary organizational models such as virtual air operations and distributed intelligence analysis. In short, they enable an organization to leverage global knowledge.

9. Return on Investment

MITRE has conducted a formal valuation (Young 2000) of the MITRE Information Infrastructure (MII), in effect the corporate knowledge management system. MITRE won a CIO Enterprise Value Award for the system (CIO 1999). The principal method for valuation uses the Norton/Kaplan balanced scorecard which measures financial, customer satisfaction, internal business processes and an organization's innovation and learning activities. Accordingly, MITRE measures both tangible and intangible benefits. Notably, MITRE measures reductions in operating costs, cost avoidance, improvements in strategic business processes and staff productivity, accessible volume of intellectual capital, and the level of collaboration fostered by the technology.

MITRE's tangible benefits fall into three principal categories: reduced operating costs, improved staff productivity, and cost avoidance. For example, fewer human resources staff are required to administer benefits by allowing staff to access and update their own human resources records or to find answers to routine questions. Analysis of call logs indicates that the HR staff now typically handle more sophisticated queries because answers to routine questions are directly accessible on line. Between 1996 and 1999 the MII enabled MITRE to save \$16.6 million in labor and material costs. The savings were made in reduced costs in human resources and administration (\$5.6 million), information systems management (\$2.9 million), financial operations (\$3.6 million), technical operations (\$2 million) and miscellaneous other services (\$2.6 million).

In addition to reducing operating costs, staff productivity was increased by the MII as measured on three tasks common to all staff: document management, daily time card submission, and purchasing. With respect to managing documents, staff used to spend tens of minutes each day converting documents for publication to others. With the MII, staff can automatically translate presentations, spreadsheets and documents into HTML, index and publish them so that they are immediately available corporate wide. Through surveys and observation, MITRE determined that the technology was saving employees at least five minutes a day. Employees can save a minute a day by filling out time cards on line as opposed to in paper. Two minutes a day was saved by allowing employees to use a purchasing card online and track purchase status directly over the MII, instead of relying on a central purchasing organization. Ready information on the MII also enhanced productivity of the corporate help desk and job pricing. By analyzing time logs, we determined that help desk staff save an average of eight minutes per call and job pricers save an average of one hour per job. By multiplying these aggregate time savings by the salaries of a conservative three-quarters of the MITRE population (\$436,800 per minute), we estimated widespread use of the MII was saving MITRE \$12.8 million in improved staff productivity. We further estimated that the number of calls handled by the help desk and the average staff salary results in a help desk cost of 56 cents a minute. The value attributed to time saved in performing job pricing was based on 600 jobs priced quarterly and the average salary of staff covering that function (\$70,000).

A final area of savings is cost avoidance. Sharing information on the MII has enabled MITRE to save significantly in fulfilling its requirements to comply with federal regulations of property management, purchasing and employee time cards. For example before the MII, MITRE sponsors had withheld three months' worth of revenue (\$22 million) because of noncompliance. After fulfilling timecards electronically on the MII, MITRE has suffered no penalties. By providing direct access to information, the MII also enables more efficient compliance with federal regulations. For example, before the MII, MITRE required about 600 clerks a year to manually conduct a government-mandated, twice-a-year audit of all computers and peripheral property associated with the dozens of contracts with the Army, Air Force, Navy and other government agencies. Today, all MITRE property is bar-coded and logged into an MII accessible database. This enables individual employees to manage their property directly from their MII web browser. It also enables government auditors to automatically generate reports or perform equipment analyses directly from the MII to satisfy their reporting, saving MITRE \$860,000 a year in clerical staff overhead (600 clerks across the company at \$9 per hour, wholly dedicated to the auditing process for four weeks a year). Finally, the MII helps reduce turnover by facilitating collaboration across geographic boundaries, including supporting employees working at home. Currently it costs MITRE about \$20,000 to process in a new employee. For example, in 1998 the MII enabled MITRE to retain 15 teleworkers, saving about \$300,000 in potential new-hire costs. Moreover, MITRE's turnover rate has remained significantly below the national average, in part a result of the high quality of work life the MII enables by lowering job frustration, which increases productivity and improves the work environment.

In addition to these quantitative financial benefits, the MII has returned important "soft" benefits. The MII provides three basic mechanisms to share knowledge: transfer folders for temporary exchange of information, document folders for published knowledge, and individual homepage and resume folders, all of which are fully indexed and stored in a globally accessible distributed file system. Analysis of web logs shows that 35 percent of all MITRE staff publish technical information daily on the MII, and approximately 60 percent retrieve technical information several times a day. Whereas corporate information collections numbered less than 100 in 1995, within less than 5 years users were able to access over 300 centrally managed collections.

Another benefit of the MII is the ease of sharing knowledge digitally. Half of MITRE's project staff use the MII as a collaborative development environment several times a day, as measured by web logs and transfer folder usage. Ninety-one percent of respondents of an all employee survey felt that the MII had a positive effect on their productivity because it enabled them to find quality information or expertise when needed. Sixty-one percent indicated they could find needed information faster than ever before. MII usage has steadily increased over time. Whereas the MII averaged 438,000 requests per month in 1995, by 1999 web logs showed that the average number of requests per month over the MII exceeded 8 million.

A key mechanism for sharing information corporate wide, transfer folders have become a hallmark of corporate collaboration. By measuring what staff put into and take out of transfer folders, the corporation has an aggregate measurement of knowledge sharing. For example, in 1999, although staffing was constant, the number of employees using transfer folders to share information rose from 2000 to 3000 and content increased 10% every month for the year. By 2002 document, staff transfer folders contained one million files and publish folders contained over 700,000 files, constituting 32 GBs of information. Average utilization rate of transfer folders hovers around 30 percent to 40 percent, with a corporate goal to achieve 50 percent or 60 percent across the company.

Finally, it is important to note that intangible benefits can be even more significant than tangible ones as they can have pervasive and direct impact on sponsor outcomes. For example, making it inexpensive and fast to assemble and run cross organizational expert teams can dramatically enhance knowledge sharing. Capturing and sharing lessons learned can foster dissemination of lessons learned, reducing cost and risks on highly complex projects.

10. Benchmarking and Metrics

Our high level knowledge objectives (e.g., ensuring our sponsors know what we know) are realized in a number of lower level measures. We intentionally describe one that is successful and one that is not to illustrate the value of measurement. For example, we monitor the use of "Fast Jump", a mechanism at the top level of the MII which allows users to directly access knowledge repositories. This is an indication of increasing the speed of discovery and likelihood of reuse of repositories. Figure 11 shows the use of fast jump, with an overall assessment of green as activity meets or exceeds a baseline. In contrast, note that of the approximately 4500 employees, we expect 3000 to have filed resumes when in fact only about 1000 presently do, so this benchmark is marked red for unsatisfactory. By 2002, due to increased focus on resume publication, 1,735 staff had resumes on line. This is an important knowledge objective because of the need to discovery experts through current resumes.

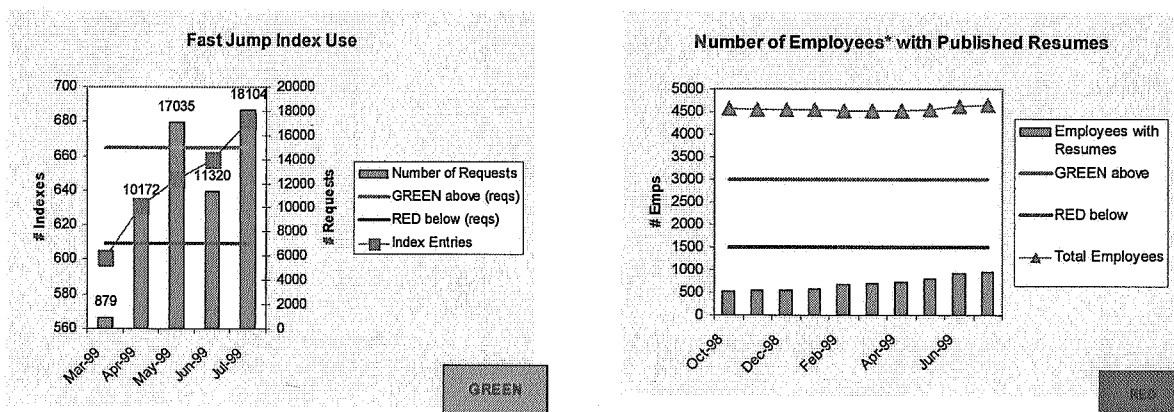


Figure 11: Benchmarking: Fast Jump and Resumes

Equally important are tools for individual collection management. We have exploited the MII in order to provide

innovative measurement approaches. The Internet Usage Profiler (IUP) shown in Figure 12 provides collection stewards, responsible for maintaining sets of MITRE's intranet Web pages, with a tool for profiling Web collections usage. This web-based application captures information about the consumption trends of MITRE staff through analysis of Web usage. The contents of the harvested Web logs record the name of the requesting machine, the requested file name, and a time stamp. IUP works by associating who owns a computer, determined from MITRE's property database, with demographic information about the owner obtained through the company's Lightweight Directory Access Protocol "white pages" directory. IUP protects individual privacy by aggregating usage across three or more employees. By combining these results in a database, we can more fully and accurately answer the question "Who is looking at my collection?" (McCready 2000). For example IUP can be used to answer questions such as:

- Which seniority level uses my Web collection the most?
- Which division is increasing usage of my collection at the fastest rate?
- Which Web collections do people I work with find worth reading?
- Is my collection's targeted audience my actual audience?

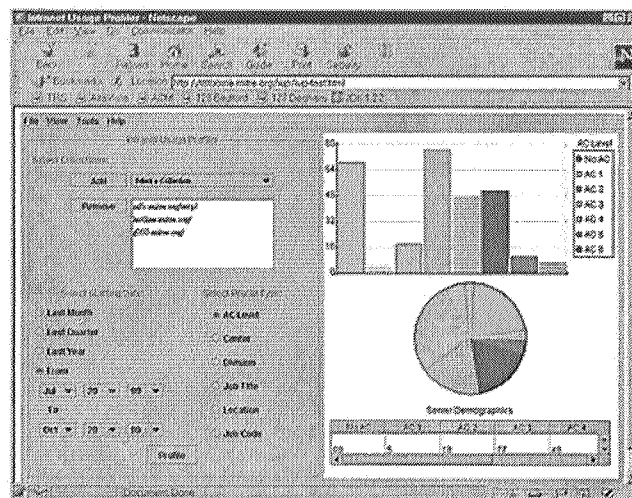


Figure 12: Content Management Aid

In addition to individual measures and tools, we continue to seek activities that lead to superior knowledge performance. For example, we focus on discovery of industry "best practices" and have explored the use of a balanced scorecard approach to benchmarking (Buck, K. 2000).

Finally, in order to provide a framework for assessing progress toward our goal state, we have designed a maturity model of knowledge management (KM) modeled after the Software Capability Maturity Model® (SW-CMM®) (www.sei.cmu.edu/cmm/). The Knowledge Management Capability Maturity Model (KM-CMM), summarized in Figure 13, describes the principles and practices underlying KM process maturity and is intended to help knowledge organizations improve the maturity of their knowledge processes in terms of an evolutionary path from ad hoc, chaotic processes to mature, disciplined KM processes. Like the SW-CMM, the KM-CMM is organized into five maturity levels:

- 1) *Initial*. At this level the knowledge process is characterized as ad hoc and occasionally even chaotic. Few processes are defined. Only a partial if any technical infrastructure to support knowledge discovery and sharing exists. As with the SW-CMM, success depends on individual effort and heroics.
- 2) *Repeatable*. At this level a basic knowledge management program is established to track requirements, content and investments. A necessary process discipline is in place to assure quality of knowledge

and/or to repeat earlier knowledge successes and/or knowledge transfer on similar projects ensuring some basic knowledge quality and reuse. A knowledge focal point (KFP) is identified who is responsible for championing knowledge management efforts within the organization.

- 3) *Defined*. At this level the process for both knowledge management and knowledge engineering activities is documented. Processes are standardized and integrated across the organization. All projects use an approved, tailored version of the organization's standard process for developing and maintaining knowledge. Manual or semi-automated methods for mapping the organizations knowledge are applied and available across the enterprise. There exists knowledge management training and intergroup coordination of knowledge discovery and dissemination (e.g., via processes such as knowledge reviews and/or knowledge sharing exchanges).
- 4) *Managed*. At this level, detailed measures of the knowledge process and product quality are collected. Both the knowledge process and products are quantitatively understood and controlled.
- 5) *Optimizing*. At this level, continuous process improvement is enabled by quantitative feedback from the process and from piloting innovative methods, ideas, and technologies. Knowledge management activities are closely aligned with business functions

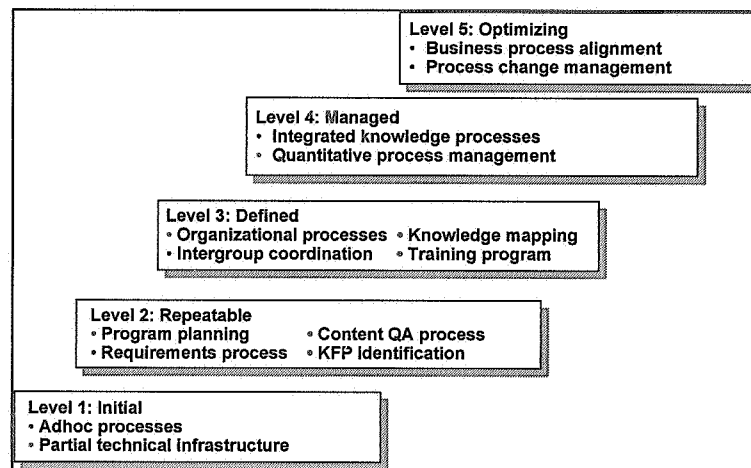


Figure 13: KM CMM

The KM-CMM can be used for organizational assessment, gap analysis, and prioritization of KM investments and improvement initiatives.

11. Conclusions and Lessons Learned

In summary, knowledge management at MITRE is successful because of a comprehensive approach, one that focuses on KM strategy, processes, repositories, communities of practice, expertise management, collaboration, benchmarking, measurement, and return on investment. It is also successful because of a executive level champions, business objective focus and benefits, and tangible staff benefits. Many lessons have been learned and continue to be learned in the continuous process of improvement including:

- Focus on people and their behaviors.
- Use and change corporate culture to drive KM
- Co-evolve of IT solutions with infrastructure and line organizations.
- Invest in knowledge areas where there exists passion and commitment.
- Capitalize on semi-automated processes such as knowledge mapping and expertise profiling.
- Ensure knowledge benefits and incentives are realized at all levels of the organization.

From a study of many organizations KM initiatives, we have discovered the following lessons (Morey, Maybury, and Thuraisingham, 2000):

1. People, and the cultures that influence their behaviors, are the single most critical resource for successful knowledge creation, dissemination, and application. *Understand and influence them.*
2. Cognitive, social, and organizational learning processes are essential to the success of a knowledge management strategy. *Focus your strategy on enhancing these processes.*
3. Measurement, benchmarking, and incentives are essential to accelerate the learning process and to drive cultural change. *Create a tailored balanced scorecard to target what you want to improve.*
4. Knowledge management programs can yield impressive benefits to individuals and organizations if they are purposeful, concrete, and action-oriented. *Make yours so.*

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